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The Effect of STEM Problem-Based Learning (PBL) on Students' Scientific Literacy and Creative Thinking Skills in Ecology Material at SMPN 37 Medan

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Abstract

The purpose of this study is to analyze the effect of applying the STEM problem-based learning on students' scientific literacy and creative thinking skills in ecology material. This study was quasi-experimental research with two two-group pretest-posttest design. The population of this research was all of the students of class VII SMP Negeri 37 Medan, academic 2024/2025. The sample of this research was taken by using a class cluster random sampling technique consisted of eight classes. Class VII-D was an experimental class taught by a STEM problem-based learning model, Class VII-E was a control class taught by conventional. The research instruments were multiple-choice tests to assess scientific literacy and essay tests to assess creative thinking skills. The data were analyzed by using a t-test. The results showed that the STEM-based problem-based learning model had a greater effect on students' scientific literacy and creative thinking skills ($p < 0.05$) compared to the conventional learning model applied to the control class. Based on the results, it can be concluded that the STEM-based problem-based learning model significantly influenced students' scientific literacy and creative thinking skills at SMP 37 Medan.

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INTRODUCTION

Education is a planned process aimed at shaping students' personalities through mentoring, where the role of adults as facilitators is crucial in guiding students' independence of thought and action (Hidayat & Abdillah, 2019). In an effort to improve the quality of education, the government has implemented the Independent Curriculum, which emphasizes literacy as the foundation for developing adaptive and competitive human resources in the global era (Firdaus et al., 2022). This curriculum also equips students with 21st-century competencies, such as critical thinking, creativity, collaboration, and communication. In line with the principles of modern science education, active student involvement is key to building understanding through direct experience. Therefore, scientific literacy is a crucial skill for students to face global challenges (Pratiwi et al., 2019).

Scientific literacy is an individual's ability to understand, use, and apply scientific knowledge to logically explain phenomena and make evidence-based decisions (OECD, 2019). However, the 2018 PISA results showed that Indonesian students' scientific literacy remained relatively low, with a score of 396, ranking 70th out of 78 countries (OECD, 2019). Research by Putri (2021) also showed that the average scientific literacy ability of students at SMP Negeri 2 Pematang Tiga was only 41.35%, categorized as low. Fuadi et al. (2020) stated that low scientific literacy is caused by a lack of training in literacy questions and a limited habit of reading scientific texts. Furthermore, Sutrisna (2021) added that the still-dominant conventional learning model makes students less accustomed to applying knowledge in real-life situations. Scientific literacy is also closely related to creative thinking skills. According to Harianto and Simanjuntak (2023), scientific literacy encourages students to ask questions, think reflectively, and test various ideas, all of which contribute to the development of creative thinking skills.

Creative thinking is a crucial 21st-century skill that needs to be developed in learning, including science subjects. In science, creative thinking plays a role in the practical realm. Science learning must align theory and facts, necessitating experimental activities. This makes creative thinking crucial in the process of designing and conducting experiments, collecting results, and organizing them into systematic knowledge and providing solutions (Hardiana et al., 2020). Furthermore, students are expected to be able to interpret material content, understand problems, and solve them in real-life contexts. Therefore, inquiry or investigation skills are needed, which are part of the scientific discovery process (Qomariyah & Subekti, 2021). However, in reality, research results show that students' creative thinking skills are still relatively low. (Nurdiana et al., (2020) revealed that of the four aspects of creative thinking, only the fluency aspect reached the moderate category (47.17%), while the flexibility (29.94%), originality (21.24%), and elaboration (29.77%) aspects were still in the low category. This indicates that students tend to be less able to express ideas in a diverse, unique, and detailed manner. Similar findings were also conveyed by (Fitriyah, 2024), who showed that the creative thinking skills of seventh-grade students in science learning were in the "poor" category with an overall average score of 36.32. As many as 93% of students scored below 60, which confirms that creative thinking skills have not developed optimally. This condition requires efforts to develop learning models that can stimulate all aspects of creative thinking, especially flexibility, originality, and elaboration.

Based on interviews conducted with science teachers at SMP Negeri 37 Medan. Problems in the field are seen from several things, including: (1) science learning still uses the lecture method and focuses on textbooks; (2) lack of use of technology; (3) in learning students are never invited to solve a problem in a class discussion forum. This kind of learning makes students less active. The application of conventional learning makes students bored, and not focused on learning, so that during learning students have difficulty in solving problems, in expressing opinions, in addition students also have difficulty identifying problems, explaining phenomena, and drawing conclusions after learning. This kind of learning process has an impact on students' scientific literacy and creative thinking becoming lower, so that learning strategies are needed that can help students to train to improve their scientific literacy and creative thinking skills (Harianto & Simanjuntak, 2023).

To address this need, learning can no longer rely on conventional teacher-centered methods but must instead focus on an approach that makes students active participants in learning activities. One approach that can be used is Problem-Based Learning (PBL). Problem-Based Learning is a student-centered learning model that uses real-life problems as the starting point for learning. According to Hasanah (2021), PBL places students in challenging situations to explore information and develop solutions independently or in groups, thereby fostering critical and creative thinking skills. Rose et al. (2024) added that PBL encourages active student engagement in applying concepts to solve real-world problems.

In addition to using appropriate learning models, the integration of approaches relevant to current developments is also necessary. One such approach is the STEM (Science, Technology, Engineering, and Mathematics) approach. STEM reflects the synergy between various disciplines: science as the foundation for understanding the laws of nature, technology as a tool to meet human needs, engineering as the application of technology to problem-solving, and mathematics as a tool for conceptualizing and quantifying problems (Simarmata et al., 2020). This approach is designed to create contextual and real-life learning experiences (Silitonga & Sipahutar, 2022). According to Khairiyah (2019), STEM-integrated learning can improve students' ability to connect knowledge from various fields and apply it to solve real-world problems. This approach also contributes to the development of critical thinking and creative skills, as well as the ability to solve complex problems. Furthermore, (Sara & Murni, 2025) reported that the implementation of the PBL model had a positive impact on students' creative thinking skills, particularly on indicators of originality and flexibility. Supporting this, (Aulya & Simanjuntak 2025) concluded that, based on research results and discussions, there was a significant impact on scientific literacy due to the implementation of the Problem-Based Learning (PBL) model with a Science, Technology, Engineering, and Mathematics (STEM) approach. Based on the description above, the researcher is interested in conducting research on the influence of STEM problem-based learning on students' scientific literacy and creative thinking skills on ecology material at SMPN 37 Medan.

RESEARCH METHOD

This study is a quasi-experimental study with a two-group pretest-posttest design. The population was all VII students of SMP Negeri 37 Medan in the 2024/2025 academic year. The sample was taken using class cluster random sampling consisting of eight classes. This study used a two-group pretest-posttest design. Class VII-D was selected as the experimental class with 28 students, and class VII-E was selected as the control class with 30 students. The research variables consisted of independent variables and dependent variables. The independent variable was the STEM-based PBL learning model. The dependent variables were scientific literacy and creative thinking skills. The measurement instruments were multiple-choice tests and that were valid and met the requirements for validity, reliability, discrimination power, and difficulty index The material used was ecology for class year VII student's in the second semester. This research was conducted in three stages: preparation, implementation, and reporting. In the preparation stage, the researcher discussed with the supervising lecturer to determine the learning model, then submitted the plan to the school, and conducted observations and interviews at SMP Negeri 37 Medan. After that, a question grid was compiled, learning tools were developed for the control and experimental classes, and instrument validation was conducted by experts. The implementation stage began with a pre-test in the first week, followed by two weeks of learning using the STEM-based PBL model in the experimental class and conventional learning in the control class. A post-test was conducted in the fourth week to measure the results. Finally, in the reporting stage, the data were analyzed statistically to draw conclusions and answer the research questions.

The science literacy score was calculated using a formula adapted from Pravitasari et al. (2015).

$$Skor = \Sigma \frac{Bi\ x\ bi}{St} \times 100\%$$

Description :
Bi = the number of items answered correctly
bi = the value of each item (adapted from PISA)
St = theoretical score

The results of the percentage calculation of scientific literacy are classified based on criteria presented in Table 1, as stated by Anas et al. (2023).

Table 1. Scientific literacy ability test percentage category

Percentage	Criteria
86-100%	Very Good
76-85%	Good
60-75%	Fair
55-59%	Inadequate
< 55%	Very Inadequate

The creative thinking ability score was calculated using a formula adapted from Handayani et al. (2021). The score obtained for each question ranged from 1 to 4 points and was then converted into a percentage using the following formula:

$$Percentage = \frac{Total\ score\ obtained}{Maximum\ total\ score} \times 100\%$$

The results of the calculation of the percentage of creative thinking ability are then classified based on the criteria in Table 2.

Table 2. Criteria for guidelines for assessing creative thinking skills

Percentage	Criteria
80-100%	Very Creative
76-85%	Creative
60-75%	Quite creative
55-59%	Lack of creativity
< 55%	Very Less Creative

Data were analyzed using the swimmer test and hypothesis testing. The normality test was conducted using the Shapiro-Wilk test, while the homogeneity test was conducted using the Levene test. The test results showed that the data were normally distributed and homogeneous with a significance value > 0.05, so the data were suitable for further analysis using the t-test.

RESULTS AND DISCUSSION

Student's Scientific Literacy

The analysis technique used was the t-test (Independent Sample t-test), with the results presented in Figure 1.

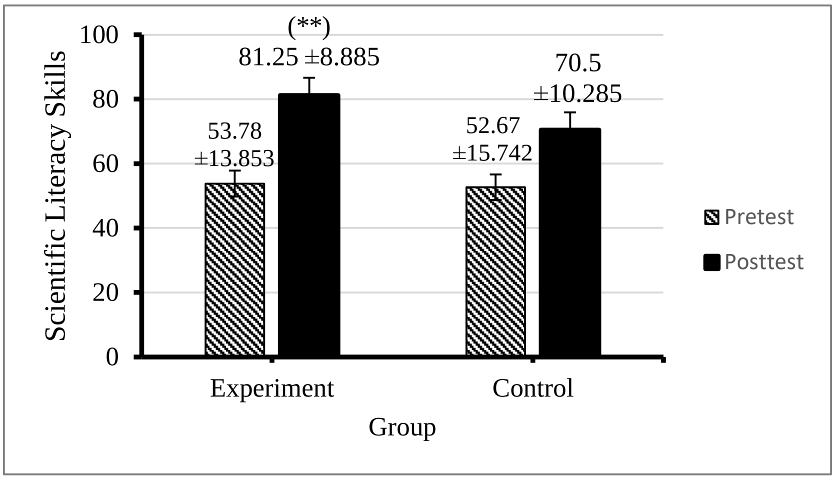

Figure 1. The Effect of STEM-Based PBL on Students' Scientific Literacy Skills (81.25 ± 8.885). The (**) sign indicates a highly significant difference compared to the control group (t-test; p = 0.000)

Based on the data presented in Figure 1, it is known that the average pretest scores of students' scientific literacy skills in the experimental and control classes did not show a striking difference. This very small average difference indicates that both groups had relatively equal initial levels of scientific literacy before being given different treatments. Thus, it can be concluded that there is no significant difference in initial mastery of scientific literacy skills between the experimental and control classes.

Posttest data showed a difference in the average scores between the experimental and control classes. The average posttest score for scientific literacy skills in the experimental class was higher than that of the control class. The Sig (2-tailed) value for scientific literacy skills was 0.000 < 0.05. These results indicate that the STEM-based Problem-Based Learning model has a very significant influence on students' scientific literacy skills.

The test of students' scientific literacy achievement for each indicator in the learning process can be seen in Table 1.

Table 3. Average Value of Science Literacy Ability Indicators of Students in the Experimental and Control Classes

No	Scientific literacy indicators	Group		t-test
		Experiment	Control	
1.	Epistemic	84.69 ±13.156	69.52 ±9.512	0.015
2.	Content	83.67 ± 6.474	70.47 ±8.910	0.004
3.	Procedural	74.40 ± 9.426	67.77 ±10.679	0.141
4..	Explaining Phenomena	81.63 ±13.745	67.14 ±10.262	0.023
5.	Evaluating and designing	77.38 ± 9.757	75.26 ±11.728	0.260
6.	Interpreting data	84.52 ± 8.651	70 ± 9.189	0.009
7..	Personal	84.69 ±13.156	69.52 ±9.512	0.015
8.	Local	83.67 ± 6.474	70.47 ±8.910	0.004
9.	Global	74.40 ± 9.426	67.77 ±10.679	0.141

Table 3 shows that students in the experimental class scored higher than students in the control class on all indicators. These results indicate significant differences between the experimental and control classes on several indicators of scientific literacy, particularly in epistemic aspects, content, explaining scientific phenomena, interpreting data, and personal and local contexts. Meanwhile, there were no significant differences in procedural indicators, evaluating and designing investigations, and global context.

STEM-oriented PBL is implemented through five stages. In the initial stage, the problem-orientation phase in the PBL model, students are presented with images or videos depicting real-life problems. This visual stimulus aims to arouse curiosity, train observation skills, and encourage students to identify and explain events. This stage contributes to improving indicators of explaining scientific phenomena, as students begin to understand events based on observation and scientific reasoning. According to Ariana et al. (2023), presenting real-life problems from the beginning of learning can improve students' ability to explain scientific phenomena rationally. This finding is supported by Azka et al. (2022), who stated that the initial stages of PBL are effective in building students' understanding of problems relevant to everyday life.

Improvements in content and epistemic knowledge indicators occur when students enter the group-organization phase and begin conducting investigations. In this activity, students read, discuss, and seek additional information from various sources. Elements of Science and Technology begin to emerge as students explore important concepts and seek information through the internet or digital books. Content knowledge develops when students understand the content or material related to a problem, while epistemic knowledge grows when students begin to evaluate information, formulate answers based on evidence, and consider the rationale behind the sources they find. Sundari et al. (2024) explain that PBL and STEM-based learning processes help students understand science not simply as memorization, but as a process of inquiry through purposeful thinking.

Indicators of using scientific evidence develop well in the developing and presenting results phase. In this phase, students present their findings through reports, graphs, or posters. This activity reflects the integration of mathematics and engineering elements, with students performing simple calculations, comparing data, and developing solutions based on the information they find. According to Rahayu et al. (2024), the use of data in learning encourages students to form opinions based on evidence, not just personal guesswork. Furthermore, Aulya & Simanjuntak (2025) state that creating final products such as posters and mind maps can improve students' ability to convey ideas systematically and logically.

Technology also plays a crucial role when students independently search for and verify information online. The use of this technology strengthens students' digital literacy and supports scientific thinking in understanding the issues being studied. This opinion is supported by Rahman et al. (2023), who stated that the use of technology encourages students to learn more actively and independently in finding relevant and reliable information. Indicators of personal and local context also increase because the issues raised in learning originate from the surrounding environment and are directly related to students' daily lives. This encourages students' emotional engagement and concern for real-life problems. Students more easily understand the importance of science in their lives. Megarahayu et al. (2023) stated that a contextual approach can build students' scientific awareness of issues surrounding them.

Student's Creative Thinking

The analysis technique used was the t-test (Independent Sample t-test), with the results presented in Figure 2.

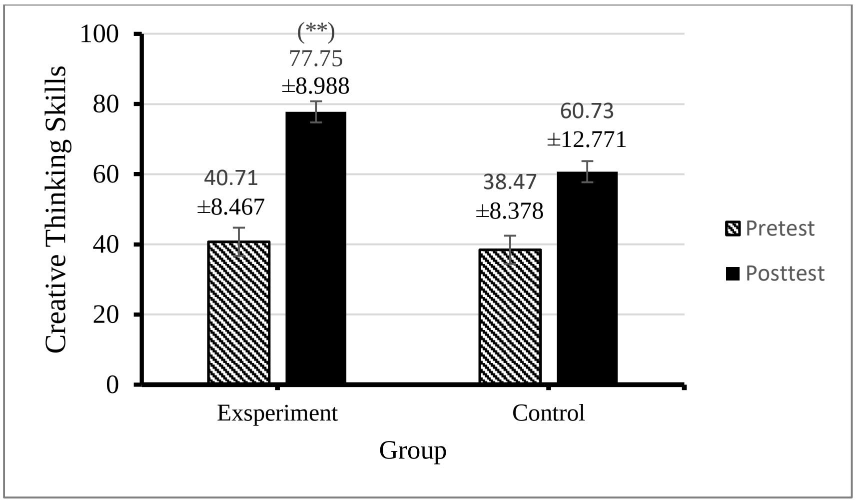

Figure 2. The Effect of STEM-Based PBL on Students' Creative Thinking (77.75 ± 8.988). The (**) sign indicates a highly significant difference compared to the control group (t-test; $p = 0.000$)

Based on the data presented in Figure 2, it is known that the average pretest scores for students creative thinking skills in the experimental and control classes did not show a striking difference. Elements of Science and Technology begin to emerge as students explore important concepts and seek information both groups had relatively equal initial levels of creative thinking skills before being given different treatments. Thus, it can be concluded that there was no significant difference in initial mastery of creative thinking skills between the experimental and control classes.

Posttest data showed a difference in the average scores between the experimental and control classes. The average posttest score for creative thinking skills in the experimental class was higher than that of the control class. The Sig (2-tailed) value for scientific literacy skills was 0.000 < 0.05. These results indicate that the STEM-based Problem-Based Learning (PBL) learning model has a very significant influence on students' creative thinking skills.

The test of students' scientific literacy achievement for each indicator in the learning process can be seen in Table 4.

Table 4. Average Value of Science Literacy Ability Indicators of Students in the Experimental and Control Classes

No	Creative thinking indicators	Group		Uji t
		Experiment	Control	
1	Fluency	93.46 ± 7.042	79.97 ± 9.974	0.000
2	Elaboration	85.07 ± 9.494	74.73± 12.683	0.001
3	Flexibility	75.39 ± 8.724	64.13± 9.867	0.000
4	Originality	67.39 ± 12.586	42.43± 13.957	0.000

Based on Table 4, students' creative thinking skills in the experimental class generally showed higher results than those in the control class across all indicators, namely fluency, elaboration, flexibility, and originality. This difference demonstrates the effectiveness of STEM-based PBL learning in developing student creativity. The t-test results support this finding. The fluency indicator had a significance value of 0.000, elaboration 0.001, flexibility 0.000, and originality 0.000. All values were below the 0.05 significance level, indicating a highly significant difference between the two groups. Therefore, it can be concluded that the implementation of the STEM-based Problem-Based Learning model had a significant positive impact on improving students' creative thinking skills across all indicators.

Students' creative thinking skills develop gradually, following each phase of the PBL model. In the problem-orientation stage, students are provided with visual stimuli and asked to express their initial opinions regarding the situation they observe. This activity stimulates fluency thinking skills, as students are encouraged to express a wide range of ideas without the pressure of being right or wrong. At this stage, the science element begins to play a role through observation and initial reasoning activities regarding the problem. According to Handayani et al. (2021), providing visual stimuli in a science context can stimulate spontaneous and varied creative ideas from students. Furthermore, according to Zakiah et al. (2023), the initial stages of PBL are highly effective in fostering students' fluency in thinking because they allow them to explore ideas without limitations.

The next stage involves organizing groups and planning investigations. Students are divided into small groups and work collaboratively to formulate questions, seek information, and devise steps to address the problem. This process strengthens the flexibility indicator, as students learn to accept and respond to diverse perspectives from their group mates. At this stage, the technology element begins to emerge through data retrieval activities from various digital sources. Pambudi et al. (2024) reported that technology in learning encourages students to think openly and critically about the information they receive. Discussions between group members also open up the possibility of thinking from multiple perspectives, consistent with Zakiah et al.'s (2023) argument that collaboration in PBL fosters flexible and adaptive thinking skills.

In the presentation and development stage of results, students begin to process information into structured solutions. They organize ideas into visual and narrative presentations. This is where the elaboration indicator develops, demonstrated by students' ability to explain ideas in detail and logically. This stage reflects the involvement of Engineering and Mathematics elements, as students not only convey ideas but also support them with data and arguments. Explain that visual learning products help students develop more structured and creative solutions. Widana et al. (2022) also add that the integration of STEM into the thinking process encourages students to organize information into a coherent and convincing final product.

The originality indicator begins to develop when students are given the freedom to choose how to present solutions. They are asked to generate original ideas based on information they have processed themselves, rather than simply copying from available sources. Although achievement in this indicator is still considered the lowest, this is understandable, considering that original thinking requires a longer and more in-depth process. Cahyani & Martini (2022) state that original thinking skills are part of higher-level creative thinking that are difficult to achieve quickly. Widana et al. (2022) also emphasize that unique new ideas often only emerge after students become accustomed to developing fluency and flexibility in their thinking.

The final stage of learning concludes with a presentation. This activity not only trains students to convey ideas confidently but also to defend arguments and respond to questions from the audience. The presentation strengthens the elaboration and originality indicators, as students are asked to explain their thought processes, not just the final results. Hidayati (2022) states that presentations in problem-based learning provide a space for students to hone their reflective and communicative thinking skills in conveying their creative ideas

CONCLUSION

There is a positive influence of the implementation of the STEM-based Problem-Based Learning model on students' scientific literacy and creative thinking skills in Ecology material in grade VII of SMP Negeri 37 Medan. This is shown by an increase in the average pretest and posttest scores. In scientific literacy, the average score increased from 53.75 to 81.75 after learning. Meanwhile, in creative thinking skills, the score also increased from 52.67 to 77.75. This increase indicates that learning with the STEM-based PBL model can help students better understand the material while developing more creative ways of thinking in solving problems.

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